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Flight Service Evaluation of Kevlar-49, Epoxy Composite Panels in Wide-Bodied Commercial Transport Aircraft

Fifth Annual Flight Service Report

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FOREWORD

This is the fifth annual flight service evaluation report on the condition of Kevlar-49 fairing panels installed on three L-1011s under NASA Contract NAS 1-11621, "Flight Service Evaluation of Kevlar-49 Composite Panels in Wide-Body Commercial Transport Aircraft." The manufacture and installation of these panels was completed in February 1973 and reported in NASA CR-112250 dated March 1973 (ref. 1). The results of inspections after the first four years of flight service were reported in refs. 2, 3, 4, and 5. The original five-year flight service program was extended for an additional five years through 1983. Annual reports will be issued describing service performance after each year of service through the ten year duration of the program.

This program is being administered by the Langley Research Center, National Aeronautics and Space Administration, with Mr. Benson Dexter of the Materials Division as the Project Engineer.

This program is being performed by the Lockheed-California Company with Robert H. Stone the Program Leader, assisted by T. L. Crawford, D. H. Horadam, J. P. Jameson, and J. Luney of the Product Support Branch.

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FLIGHT SERVICE EVALUATION OF KEVLAR-49
EPOXY COMPOSITE PANELS IN WIDE-BODIED
COMMERCIAL TRANSPORT AIRCRAFT

Fifth Annual Flight Service Report

INTRODUCTION AND BACKGROUND

The subject program on flight service evaluation of Kevlar-49 fairings consists of fabrication, installation, and flight service of eighteen secondary structural panels; six on each of three L-1011s. The three participating airlines are Eastern, TWA, and Air Canada. Fabrication and installation of the panels was completed in February 1973, with initiation of flight service occurring in early 1973 on all three aircraft.

In all of the prototype fairings, Kevlar-49 fabric comparable in fabric weave and thickness per ply to the baseline fiberglass, was substituted for the fiberglass on a ply-for-ply basis. This required no other design changes or development of new tooling for layup and cure, but still provided a weight savings of 25-30 percent. These six parts are as follows:

- A left-hand and right-hand set of a large 152- by 170 cm (60- by 67-inch) sandwich wing-body fairing panel. The exterior skin is 0.05 cm (0.02 in.) thick with 1 ply 181 style Kevlar-49 fabric and 2 plies 120 style Kevlar-49 fabric. The interior skin is 0.04 cm (0.015 in.) thick with three plies of 120 style Kevlar-49 fabric. The honeycomb core is Nomex with 0.3 cm (1/8 in.) cells, and 0.05 gm/cm³ (3.0 lb/cu ft) density. Overall panel thickness is 2.24 cm (0.88 in.), with a solid laminate edge 0.25 cm (0.10 in.) thick built up of 181 style Kevlar-49 plies (figure 1, Appendix A).
- A left-hand and right-hand set of a small 23- by 84-cm (9- by 33-in.) solid laminate wing-body fillet panel. The laminate incorporates 9 plies of 181 style Kevlar-49 fabric and is approximately 0.2 cm (0.1 in.) thick (figure 2, Appendix A).

- A left-hand and right-hand set of an aft engine sandwich fairing 76- by 183-cm (30- by 72-in.) approximately. The skins are 0.05 cm (0.02 in.) thick with 1 ply 181 style Kevlar-49 fabric and 2 plies 120 style Kevlar-49 fabric. The Nomex core is identical to that used in the wing-body fairing, except for thickness, and the overall panel thickness is 0.64 cm (0.25 in.). The aft engine fairing also has a solid laminate edge member 0.25 cm (0.10 in.) thick (figure 3, Appendix A).

The Kevlar-49 panels used the same resin system as the production fiberglass parts. A 120°C (250°F) curing, 82°C (180°F) service epoxy (Hexcel's F-155) was used in the wing-body fairing and under-wing fillet panels; and a 177°C (350°F) curing, 150°C (300°F) service epoxy (Hexcel's F-161) was used in the aft engine fairings. Two fabric weave styles of Kevlar-49 were used. The Kevlar-49 style 181 is an 8-harness satin weave similar to the 181 fiberglass weave, 0.23mm. (9 mils) per cured ply and 0.17kg/m² (5.0 oz/yd²) dry weight. Kevlar-49 style 120 is a plain weave, 0.13mm. (5 mils) per cured ply and 0.06kg/m² (1.8 oz/yd²) dry weight. Both fabric styles incorporate light denier Kevlar-49 yarns, 380 denier for style 181, and 195 denier for style 120.

All of the parts have an outer layer of flame-sprayed aluminum and top-coat applied according to standard production procedures used on the baseline fiberglass parts. The actual weight savings achieved by this direct substitution of Kevlar-49 for fiberglass averaged 26 percent for the six parts. Further details on Kevlar-49 part design and fabrication are given in NASA CR-112250 (ref. 1), which is the final report of the fabrication and installation phases of the program.

The first annual inspection results are given in NASA CR-132647 (ref. 2). The Air Canada and TWA panels were inspected at Lockheed in this case due to special circumstances, while Eastern personnel inspected the Eastern panels at Miami.

For the second annual inspection and all subsequent inspections, the program scope was expanded as follows to obtain more complete information and documentation of part conditions:

- A Lockheed Engineering representative is present for each annual inspection at the airlines' maintenance bases.
- Three of the six panels (one of each left-hand and right-hand set) are removed for thorough inspection, weighing, and inspection of fastener holes and interior surface conditions.
- The airlines provide reports to Lockheed on all incidences of damage and repair occurring in service.

The second, third, and fourth annual inspections were conducted in accordance with this expanded scope, and are reported in NASA CR-132733 (ref. 3), NASA CR-145141 (ref. 4), and NASA CR-145326 (ref. 5).

As discussed in previous reports, the TWA panels were removed after approximately one year (2400 hours) of service, and reinstalled on a second TWA L-1011 for continuation of flight service testing. The reinstallation on TWA aircraft N31030 required some rework and repair of the panels, particularly in the case of the aft engine fairing panels, where relocation of all fastener holes was required. This rework activity is reported in detail in the Second Flight Service Report (ref. 3). The aircraft on which these parts were reinstalled was delivered to TWA in August 1975, and have since been inspected annually in accordance with the expanded program scope.

During 1977, a five-year extension to the program was received from NASA for a total of ten years' flight service of the Kevlar-49 fairings. This extension carries the program from 1979 through 1983, and annual inspections of the three ship sets will take place in accordance with the expanded program scope outlined above. In 1978, additional funding was received for reinstallation of the Eastern panels onto a second Eastern L-1011. This reinstallation, which is scheduled for November 1979, is required because the original aircraft is being leased to another carrier.

Since this flight service program was initiated in 1973, a considerable number of Kevlar-49 components have been installed as production components on the L-1011 and other aircraft, and many other applications are being considered. The fairings in this program remain the longest service life Kevlar-49 components in commercial aircraft flight service, where they see over 2000 flight hours per year. As the only organic filamentary reinforcement being used in aircraft structures, Kevlar-49 has unique chemical and mechanical characteristics. Two characteristics which have been of concern are the pick-up of moisture in the fiber, and the low resin/fiber interface bond. The detailed monitoring of the fairings' performance in this program provides information on long-term mechanical behavior and environmental durability which has applicability to many other programs, and adds significantly to confidence in the use of this material.

PANEL INSPECTIONS

The fifth annual inspection of the Kevlar-49/epoxy fairings on Eastern Ship N314EA (Serial No. 1022) took place at the Miami Maintenance Base on February 14, 1978. The panels had been in flight service five years, with 13,415 flight hours at the time of inspection. In the intervening nine months since the previous inspection, the panels had accumulated 2015 flight hours.

The three left-hand fairing panels were removed for inspection by Eastern Maintenance, and the right-hand parts were inspected in-place on the aircraft. Inspection was by visual examination and coin-tapping for delaminations and skin-core disbonds. The panels taken off the aircraft were cleaned to remove excessive dirt and residue, and were then dried and weighed. These panels were then inspected for the condition of fastener holes and the inner surface, as well as the outer surface condition, which was inspected on all six parts.

The fifth annual inspection of the Air Canada panels on Ship CF-TNB-502 (Serial No. 1021) took place on October 19, 1978 at the Montreal Maintenance Base. The left-hand wing-body fairing and underwing fillet panels, and the right-hand aft engine fairing were removed for inspection, while the opposite set of panels were inspected in-place on the aircraft. The fairings had been in service over 5.5 years, and had 12,835 flight hours as of the date of inspection. In the intervening year since the previous inspection, the panels had accumulated 2836 flight hours. Inspection was by visual examination, coin-tapping, and weighing as described above for the Eastern panels.

The fairings installed on TWA Ship N31030 (Serial 1111) were inspected at the Los Angeles Maintenance Base on November 1, 1978. The fairings at that time had 7459 flight hours on Serial 1111. These panels had seen 2404 hours on Serial 1026 prior to their removal and reinstallation, for a total of 9863 flight hours. In the intervening year since the previous inspection the panels had accumulated 2377 flight hours. The three panels removed for inspection were the right-hand wing-body fairing and underwing fillet panels, and the left-hand aft engine fairing. This was the opposite set of those removed in 1977. Inspection procedures were the same as described above for the Eastern and Air Canada panels.

All three inspections were conducted with the participation of Lockheed Engineering, and with the assistance of airline maintenance personnel in removal and reinstallation of the panels. Photographs were taken of all panels and areas containing defects, damage, or other conditions of special interest. Photographs were provided by Air Canada in Montreal, by the Lockheed Photography Department at TWA in Los Angeles, and by a commercial photographer at Eastern. Detail observations at the three inspections are given in Appendices A, B, and C.

DISCUSSION OF INSPECTION RESULTS

The Kevlar-49 panels continue to perform satisfactorily in service with no major damage or defects requiring corrective maintenance. Minor impact damage has occurred, primarily on the large wing-body fairing sandwich panels, which are in an area subject to ground handling damage and damage from runway objects. In several instances, the skins have been penetrated exposing the honeycomb, but the airlines do not regard this as a serious occurrence as these are lightly loaded nonstructural components which only take aerodynamic

loads. Damage is therefore left unrepaired for an indefinite period, or else given a cosmetic repair.

Several new damage occurrences were noted on the wing-body fairings. These included a deep gouge with penetration to the honeycomb on the Eastern left-hand fairing, a similar gouge on the Air Canada left-hand fairing panel, and a third similar deep gouge on the TWA left-hand fairing. The Air Canada left-hand panel also had a slight gouged area on the forward solid laminate edge member. The Air Canada left-hand fairing also had a slight crack 0.8 cm (0.3 inch) length on the inner surface which is the first time damage has been observed on the inner surface of any of the fairings. There is a space behind these fairings with access, so that ground-handling damage such as dropped tools is possible.

The above incidences of damage where penetration to the core was observed, were reported to airline maintenance. However, no maintenance or repair action was taken on these occasions for any of the three parts.

A significant observation was the absence of any detectable damage growth or propagation on any of the impact cracks noted during previous inspections of the wing-body fairings. In some cases, the cracks have remained unchanged in appearance, size, and extent of delamination for three years.

The other damage condition which has been typically observed on the Kevlar-49 panels has been fraying and elongation of fastener holes. These have, in all instances, been minor conditions which have not required maintenance action or repair. Elongation of the fastener holes has occurred in a random distribution, and has been noted primarily on the underwing fillet panels. This condition is comparable to hole elongation on similar fiberglass panels which is a fairly common occurrence according to the airlines. The cause of the elongation is concentrated or nonuniform bearing loads possibly resulting from installation problems. There has been relatively little increase in the incidence or severity of this elongation, and in the 1978 inspections no increased elongation was observed over 1977 results.

The fastener hole fraying appears to be a general occurrence on Kevlar-49 holes and edges where less than optimum machining procedures have been used. The fraying noted on these parts appears to be primarily the result of the initial machining operation, as this condition has remained essentially unchanged with increasing service life. These parts were fabricated in 1972 when development of Kevlar-49 machining techniques was in a very early stage, and the degree of fraying may therefore be more severe than for currently fabricated parts. The elongated holes in the underwing fillet have more fraying than the other holes, indicating that in-service loads can aggravate the initial fraying. There is no evidence that the frayed condition in any way affects part performance.

A different type of damage was initially observed in 1977 on the right-hand TWA wing-body fairing. This was a large teardrop shaped disbond area 11.4 by 2.5 cm (4.5 by 1 inch) in area. This had an associated deep concave

depression indicative of core crushing, but the paint and flame spray were intact with no cracks or crazing. This disbond had not increased in area or depth since the 1977 inspection. A similar, but smaller disbonded and depressed area was observed in 1976 and 1977, and has not grown since the 1977 inspection. Two additional disbonds were observed which were much smaller in area and depth and one of these had also been observed in 1977. These occurrences, which are unique to this particular fairing, are probably related to a repair made when the part was reinstalled on Ship 1111 (ref. 3). This repair was not documented, but apparently consisted of replacement of a damaged core area, extending partially through the core thickness, with a microballoon-filled potting compound. This is not therefore a Kevlar-49-related problem, but as it is a highly visible condition it will be monitored in future inspections.

The Kevlar-49 parts have not been affected to any discernible degree by exposure to Skydrol or other aircraft fluids, although the wing fairings and fillets are adjacent to hydraulic lines. Paint adhesion to the Kevlar-49 surfaces appears to be comparable to fiberglass parts, as would be expected.

The Kevlar-49 parts have been weighed on the occasions when they have been removed. The effects of paint loss, repainting, resealing, and repair have masked any weight change due to moisture pickup; and determination of weight changes has been hampered by the lack of suitable balances at the airline maintenance bases. A balance was brought from Lockheed to the TWA base in Los Angeles for weighing of the small underwing fillet panel. An accurate weight was obtained on the right-hand fillet (Appendix C), and the weight on this part will be monitored throughout the remainder of the program.

SUMMARY OF RESULTS AND CONCLUSIONS

The Kevlar-49 fairing panels continue to perform satisfactorily and are free of major damage or defects after five years of service and a total of 36,000 flight hours on the three aircraft.

Two types of minor damage have been noted: cracks resulting from impact observed principally on the wing-body fairings; and fraying and elongation of fastener holes. The cracks are caused primarily by ground handling, while the fastener hole conditions appear to be primarily the result of the initial drilling and installation procedures. The absence of crack growth or significantly increased hole elongation, and the random, limited occurrence of the hole elongation indicates that Kevlar-49 is resistant to damage propagation under the relatively light loading conditions typical of fairings. The fastener hole fraying is the only damage condition observed on the Kevlar-49 parts which is not also typical of similar fiberglass parts. The fraying has not increased in severity with increasing service life, and does not have any apparent effect on part performance.

The Kevlar-49 panels have been free of delaminations, and only a few minor skin-core disbonds have occurred. No defects have been observed which

can be attributed to moisture or other environmental factors. These findings indicate that two properties of Kevlar-49 which have been of concern - the poor resin-fiber interface bond and the moisture pickup of the Kevlar-49 fibers - have not seriously affected part performance.

In summary, Kevlar-49/epoxy appears to provide service life and structural performance for lightly loaded secondary structures equivalent to that of fiberglass/epoxy.

APPENDIX A

DETAIL OBSERVATIONS OF KEVLAR-49 FAIRING PANELS - EASTERN AIR LINES AIRCRAFT N314EA (SERIAL NO. 1022), FEBRUARY 1978

The three left-hand fairing panels were removed for inspection of fastener holes and interior surface conditions and for weighing (figures 1, 2, and 3). The right-hand panels were inspected on the aircraft. Detail observations on these parts are outlined below:

Left-Hand Wing-Body Fairing

1. The panel weight was 6.9 kg (15.2 lb). The original recorded panel weight was 7.0 kg (15.5 lb).
2. A deep gouge and associated crack was noted in the upper forward area of the exterior surface (figure 4). The maximum depth was 0.06 cm (1/16 in.), and the honeycomb was exposed. The length of this crack was approximately 2.5 cm (1 inch) across the chord from end to end of the crack. There was no associated delamination except immediately adjacent to the crack. This was definitely caused by impact, probably from ground handling.
3. A speed tape patch first noted in 1975 remains unchanged in appearance (figure 5) since the last inspection. This patch is approximately 3.2 cm by 4.5 cm (1 1/4 by 1 3/4 inch) in area.
4. An area of flame spray loss noted in 1977 had increased in area, but further observation confirmed that no damage to the Kevlar-49 was associated with this condition.
5. Slight fraying was observed on most fastener holes particularly along the bottom edge (figure 6). The condition is observed primarily on the inner surface, but is also visible from the exterior surface.
6. Several of the fastener holes showed varying degrees of elongation. Only three holes were elongated significantly, however.
7. The inner surface was deformed around the fastener holes on the lower edge with a convex appearance (figure 7) as if partial fastener pull-through had occurred.
8. A delaminated area on the inner surface, 19.1 by 1.9 cm (7 1/2 by 3/4 in.), observed in the 1975 and 1977 inspections, was unchanged in appearance or extent.

Left-Hand Underwing Fillet

1. The panel weight was 0.9 kg (2.1 lb). The previous weight, recorded in 1977, was 1.0 kg (2.2 lb).
2. The Kevlar-49 exterior surface still had considerable paint loss with some bare Kevlar-49 surface exposed (figure 2). No apparent effects or damage are associated with these areas. This part is not exposed to sunlight, so there should be no ultraviolet effects on the bare Kevlar-49 surface.
3. Fraying of fastener holes was visible particularly on the inner edge, and more pronounced on the lower edge (figure 8). No increased degree of fraying was observed over that noted in 1977.
4. The same elongated holes were observed as in the 1975 and 1977 inspections with no increase in degree of elongation. These include three severely elongated holes.
5. A slight gouge on the upper forward area of the inner surface, observed in 1977, had not changed in appearance.

Left-Hand Aft Engine Fairing

1. The panel weight was 3.3 kg (7.2 lb). No previous weight had been recorded.
2. Fraying was observed on all fastener holes, and was more evident viewed from the inner surface. The fraying was particularly severe on the lower aft edge. The upper aft edge, and a majority of the holes on the upper and lower edges were also severely frayed. Intercostal holes were less frayed, for the most part, but a few slightly elongated holes were observed (figure 9).
3. No surface damage or defects were noted on either the external or inner surfaces.

Right-Hand Wing-Body Fairing

1. Several surface cracks observed in previous inspection were unchanged in appearance or extent:
 - A 1.3 cm (1/2 in.) crack between the fifth and sixth holes from the top along the forward edge (figure 10)
 - A 0.3 cm (1/8 in.) ding in the lower center area
 - A 0.3 cm (1/8 in.) crack in the aft center area

- A 0.6 cm (1/4 in.) crack in the panel center, possibly only in the paint
- A 0.8 cm (5/16 in.) crack in the lower forward area

There was no associated disbonds or delamination with these cracks.

Right-Hand Underwing Fillet

1. No evidence of fastener misalignment or installation problems.
2. Slight paint loss in the upper area with light scratches, but no evidence of damage to the Kevlar-49 surface.

Right-Hand Aft Engine Fairing

1. No fastener misalignment. No surface damage or paint loss except around a few of the fasteners.

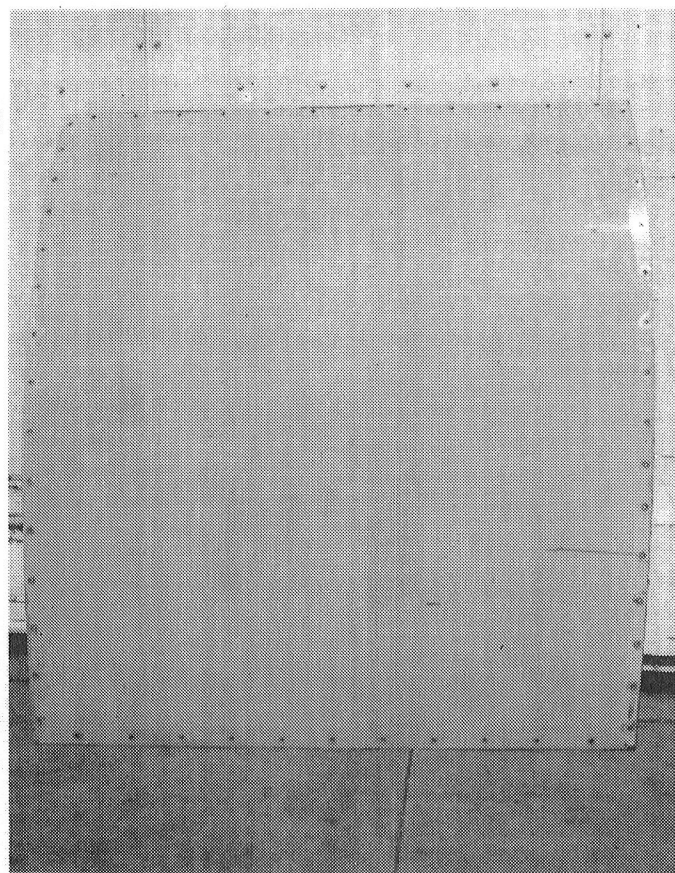


Figure 1. - Eastern left-hand wing-body fairing - exterior.

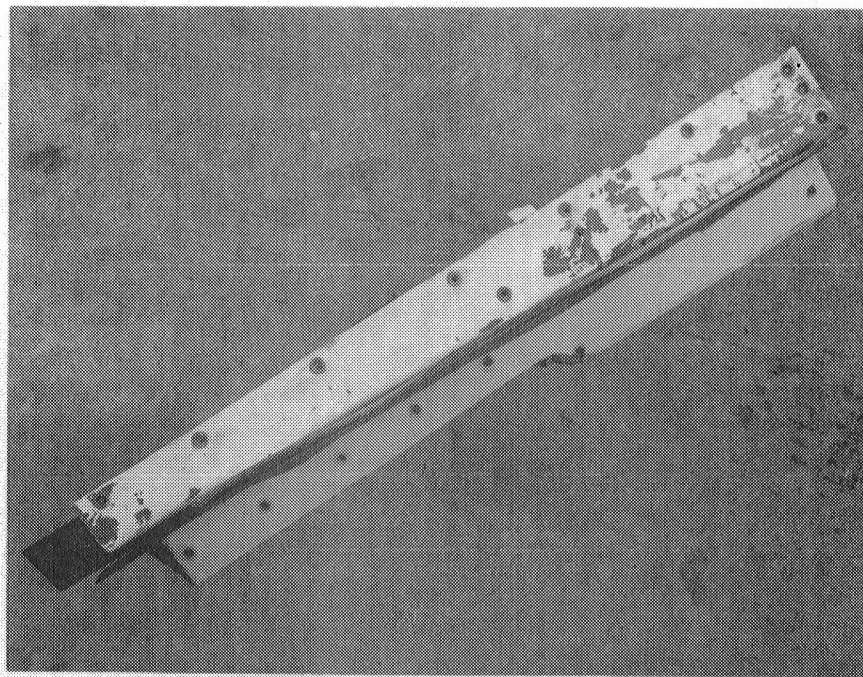


Figure 2. - Eastern left-hand underwing fillet - exterior.

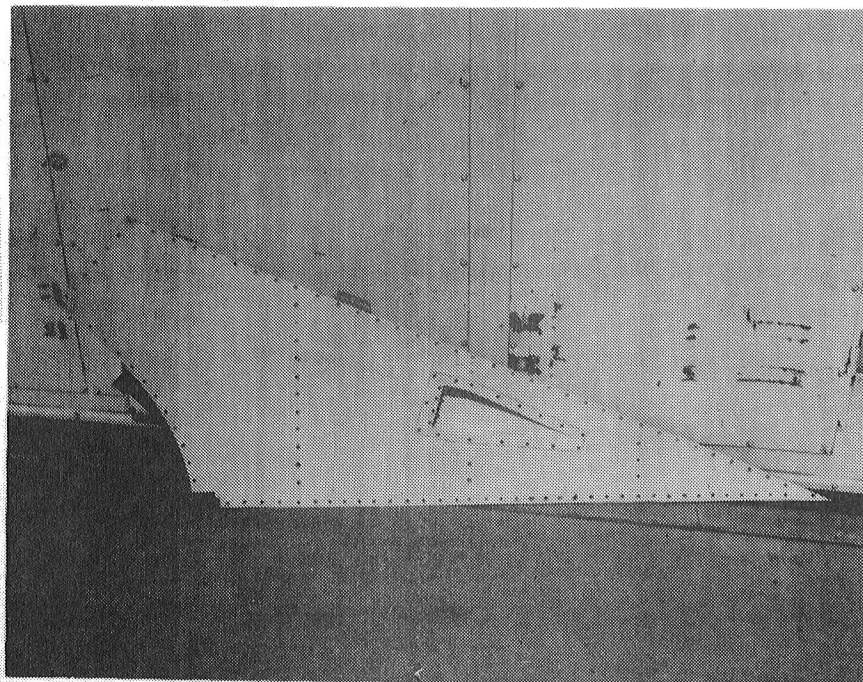


Figure 3. - Eastern left-hand aft engine fairing - exterior.



Figure 4. - Eastern left-hand wing-body fairing - deep gouge and crack with exposed honeycomb, 2.5 cm (1 in.) length.

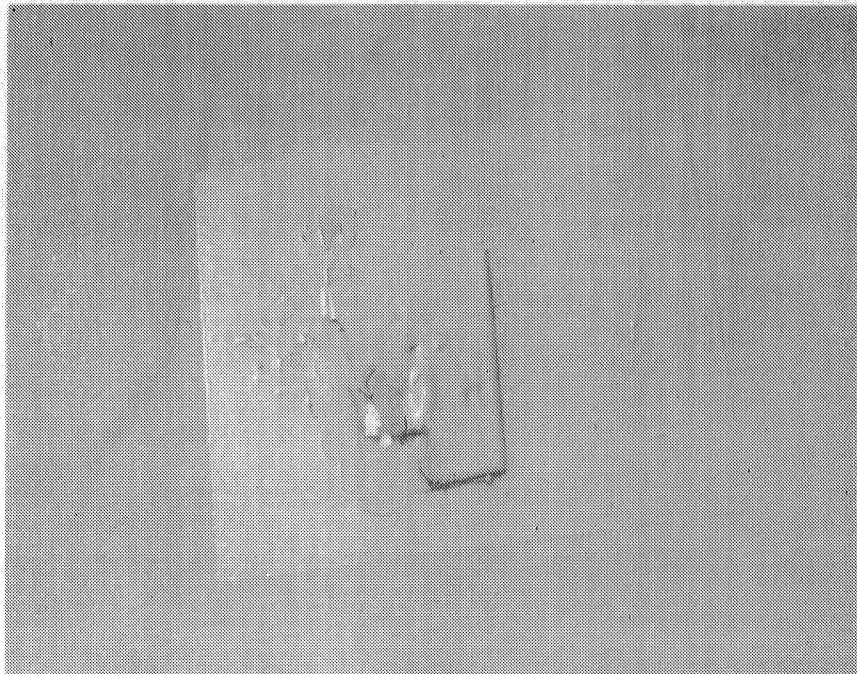


Figure 5. - Eastern left-hand wing-body fairing - speed tape patch, 3.2 by 4.5 cm (1 1/4 by 1 3/4 in.).

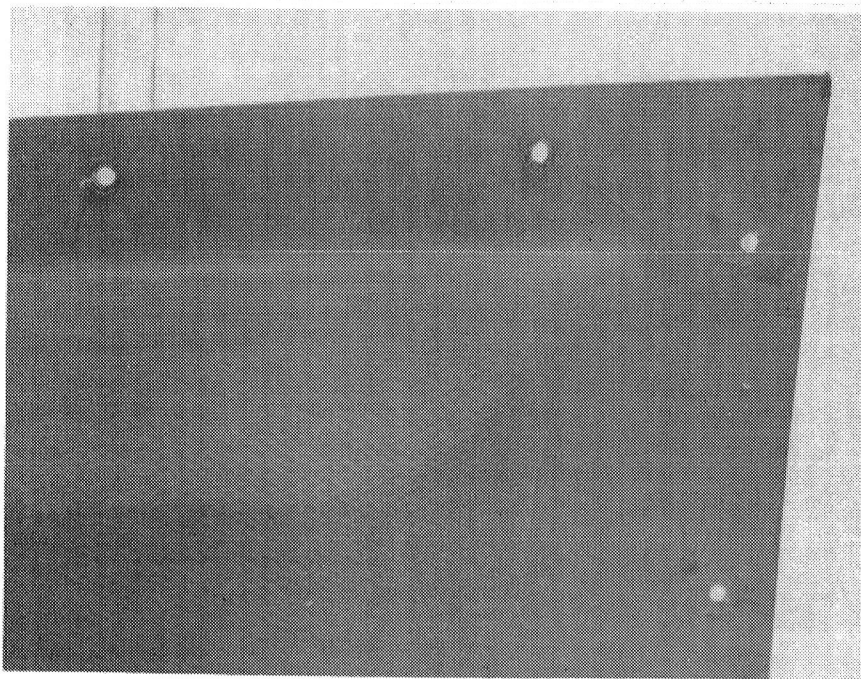


Figure 6. - Eastern left-hand wing-body fairing - typical frayed fastener holes.

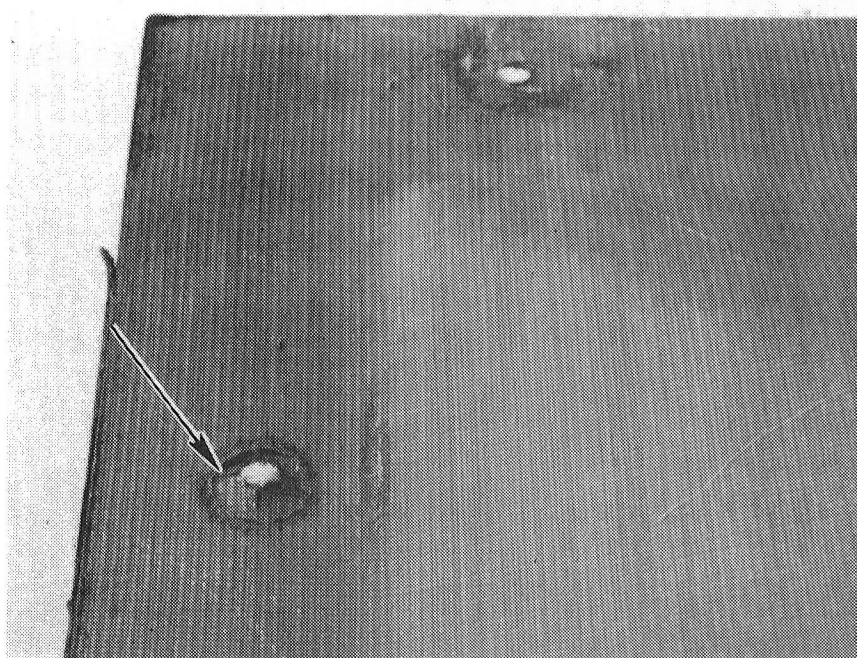


Figure 7. - Eastern left-hand wing-body fairing - elongated hole with convex deformation on lower edge.

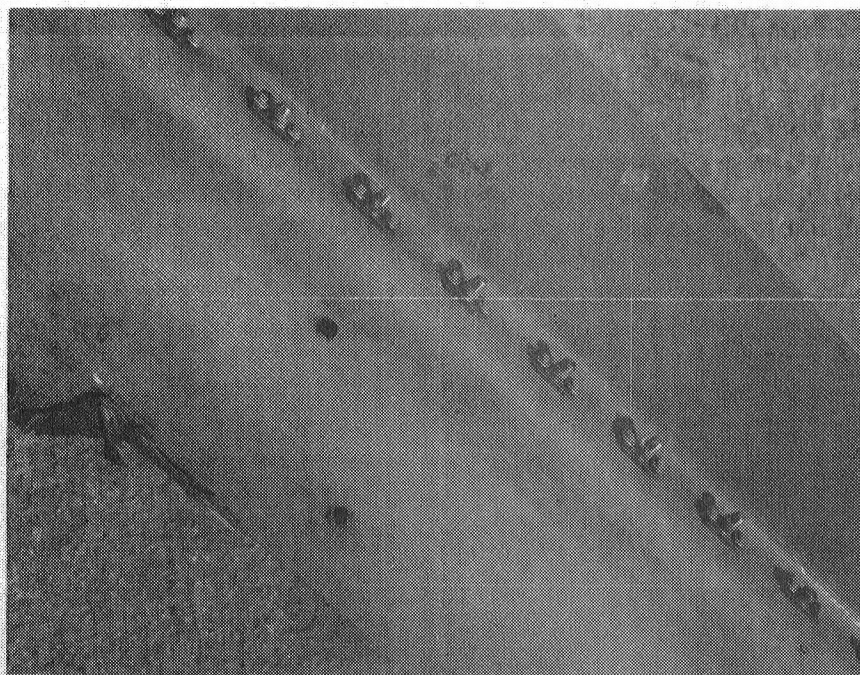


Figure 8. - Eastern left-hand underwing fillet - frayed fastener holes.

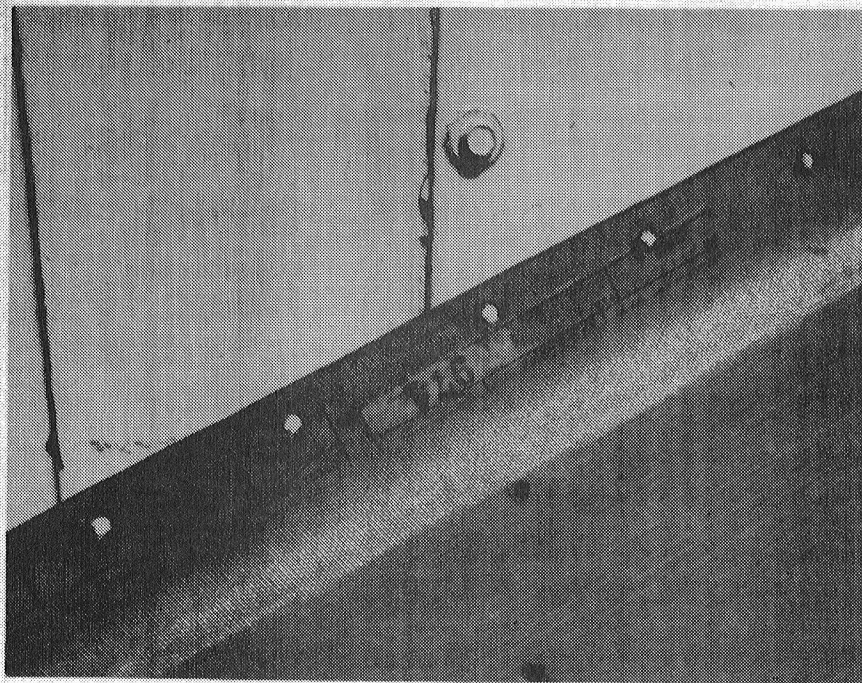


Figure 9. - Eastern left-hand aft engine fairing - frayed and elongated fastener holes.

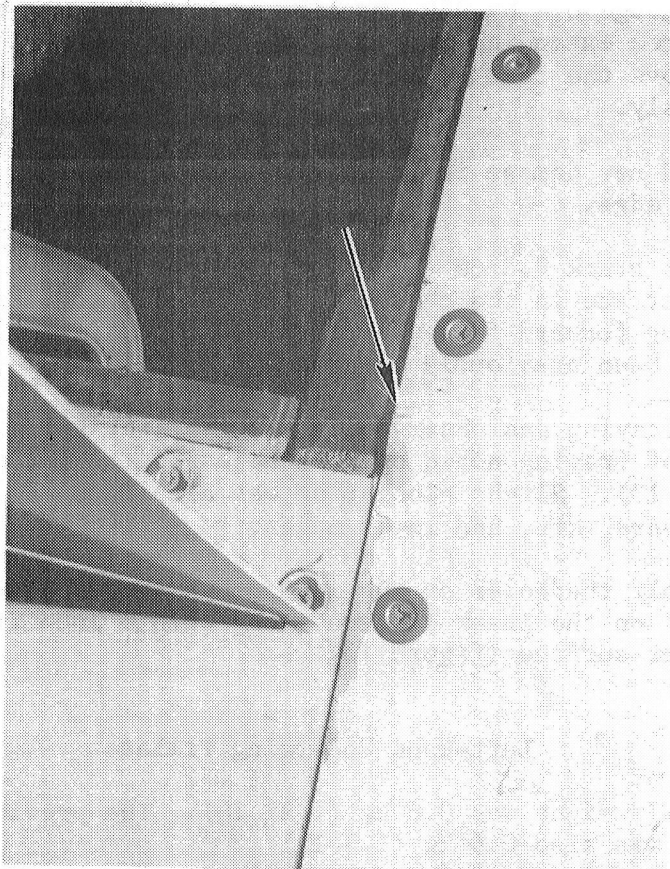


Figure 10. - Eastern right-hand wing-body fairing - crack on forward edge 1.3 cm (1/2 in.) length.

APPENDIX B

DETAIL OBSERVATIONS OF KEVLAR-49 FAIRING PANELS - AIR CANADA AIRCRAFT CF-TNB-502 (SERIAL NO. 1021), OCTOBER 1978

Three of the six Kevlar-49 fairing panels were removed for inspection of fastener holes and inner surface conditions. These were the left-hand wing-body fairing and underwing fillet panels, and the right-hand aft engine fairing.

Left-Hand Wing-Body Fairing

1. The panel weight was 6.9 kg (15 1/4 lb). The previous recorded panel weight in 1977 was 7.0 kg (15 3/8 lb).
2. A surface crack 3.2 cm (1 1/4 in.) long in the upper aft area, first observed in 1974 and then in subsequent inspections, had been repaired since the 1977 inspection. The crack had been filled in with resin and coated with conductive paint (figure 11). There was no record of this maintenance action.
3. A deep gouge 0.4 by 0.6 cm (5/32 by 1/4 in.) was noted in the upper area extending into the core, with a slight delaminated area above the crack (figure 12). This had not been observed previously.
4. A second new damage incident was a gouged area on the lower, forward edge.
5. A slight crack 0.8 cm (5/16 in.) in length was observed on the inner surface in the center of the panel with a slight delamination extending forward from the crack 0.8 cm (5/16 in.). This damage had not been previously observed.
6. Slight fraying was observed on all fastener holes, with the greatest degree of fraying noted on some holes on the aft and lower edges (figure 13). Slight elongation was also noted on several holes on the forward, aft, and lower edges.
7. About half the holes on the lower edge showed a severe fastener mark-off on the inner surface along with a localized deformation of the inner surface (figure 13).

Left-Hand Underwing Fillet

1. The panel weight was 0.6 kg (1.23 lb). The previous weight noted in 1976 was also 0.6 kg (1.3 lb).

2. The exterior surface had extensive paint loss with the Kevlar-49 surface exposed in the upper area. No damage to the laminate was observed on either surface.
3. Slight fraying was observed in most of the fastener holes (figure 14). Elongation was also observed in most of these holes. Eight of the elongated holes had a significant degree of deformation with elongations to 0.6 cm (1/4 in.) and in one case 0.7 cm (9/32 in.) from the original 0.5 cm (3/16 in.) size (figure 15). These holes had a random distribution on the fairing.

Right-Hand Aft Engine Fairing

1. The panel weight was 2.4 kg (5.2 lb). The original panel weight was 2.3 kg (5.0 lb), which was also the weight recorded in the 1976 inspection.
2. No damage or defects were noted on either surface.
3. Slight fraying was observed on all fastener holes (figure 16), but the degree of fraying observed on this component is significantly less than any of the other Kevlar-49 aft engine fairings. The aft top edge had more fraying around the holes than the other edges.
4. Slight elongation was observed on several holes, with only one hole badly elongated along the lower edge (figure 16).
5. The intercostal holes (which go through the honeycomb) also had slight fraying. One intercostal hole was significantly elongated, while five others were slightly elongated (figure 17).
6. Two patch areas at the extreme forward and aft edges of the fairing were unchanged in appearance since originally observed in 1974 (figures 18 and 19). The patches are dark colored and fibrous, and may be some type of electrical tape overcoated with resin.

Right-Hand Wing-Body Fairing

1. Two cracks observed in previous inspections were unchanged in appearance or extent:
 - A 0.3 cm (1/8 in.) crack in the panel center first observed in 1976
 - A 0.6 cm (1/4 in.) crack in the forward center area first observed in 1975.

Right-Hand Underwing Fillet

1. Considerable paint loss was observed with exposed Kevlar-49 surface in the upper area (figure 20), but with no damage to either surface. This area is not exposed to sunlight or ultraviolet.
2. A slight bulging of the lower aft edge was noted indicating a possible fit problem during installation. No fastener misalignment was observed, however.

Left-Hand Aft Engine Fairing

1. No damage or defects were observed on the exterior surface.

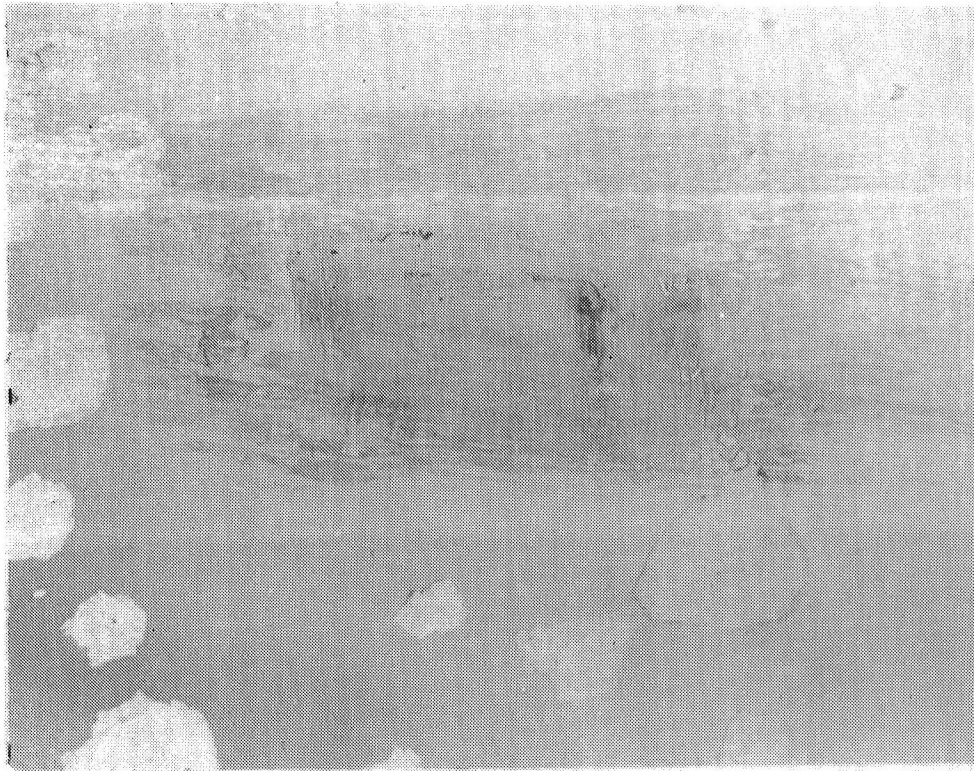


Figure 11. - Air Canada left-hand wing-body fairing - repair area on exterior.



Figure 12. - Air Canada left-hand wing-body fairing - deep gouge with exposed core 0.4 cm by 0.6 cm (5/32 by 1/4 in.).

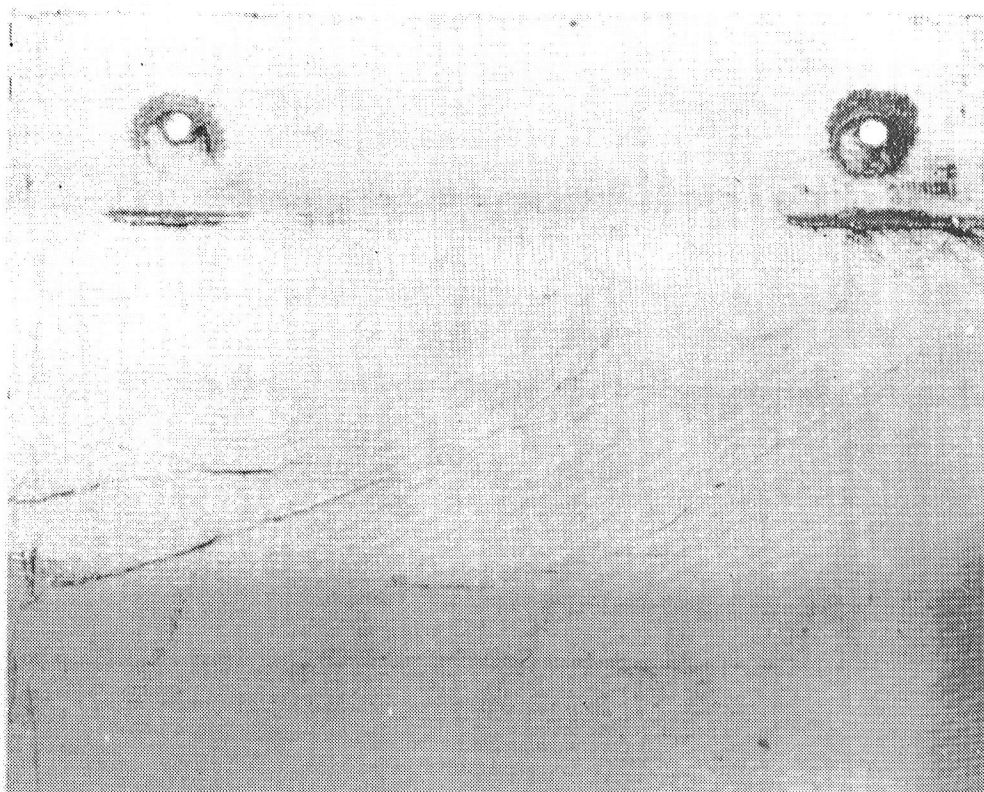


Figure 13. - Air Canada left-hand wing-body fairing - frayed fastener holes on lower edge, with deformation and mark-off of laminate around holes.

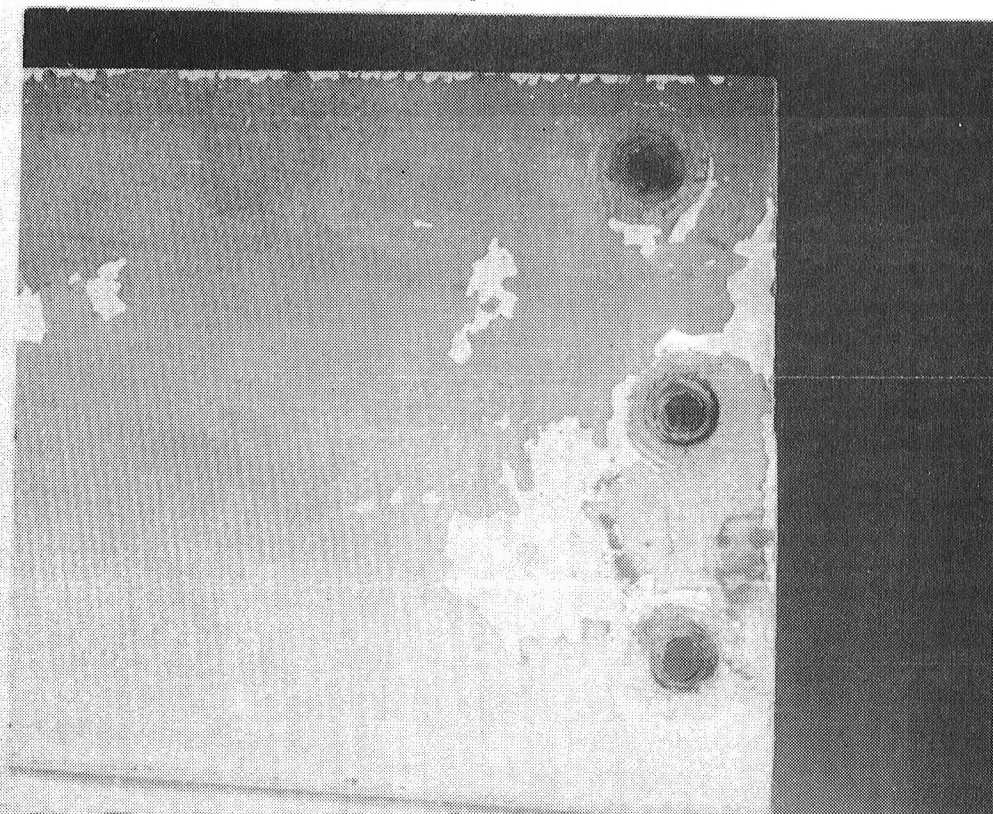


Figure 14. - Air Canada left-hand underwing fillet - typical frayed fastener holes.

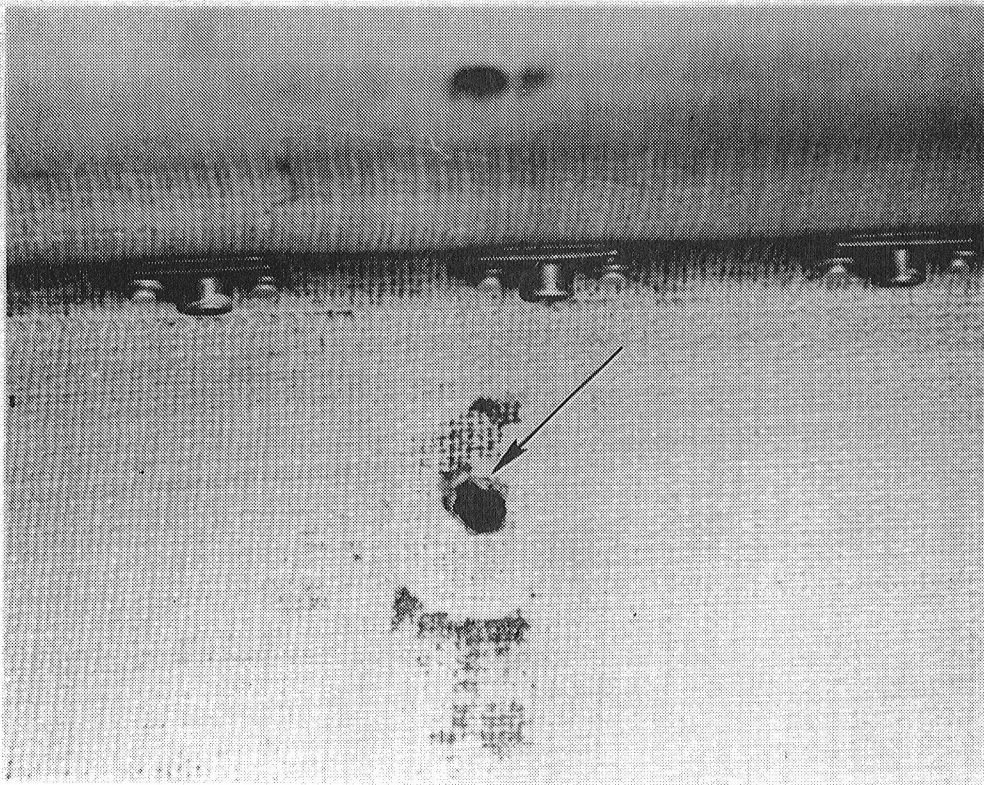


Figure 15. - Air Canada left-hand underwing fillet - badly elongated fastener hole.

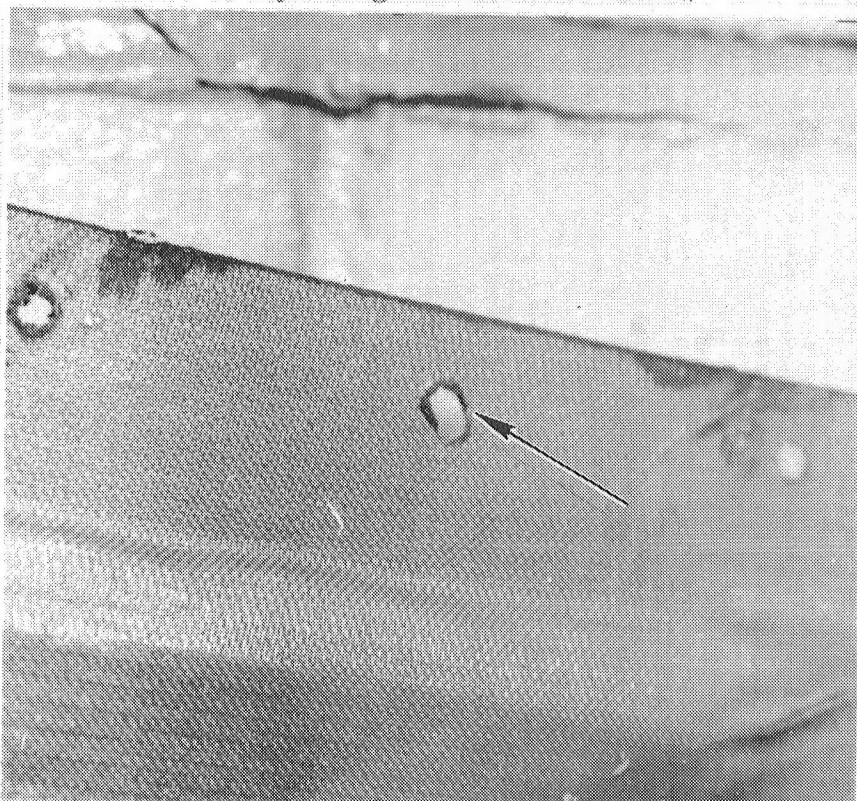


Figure 16. - Air Canada right-hand aft engine fairing - frayed holes with badly elongated hole.

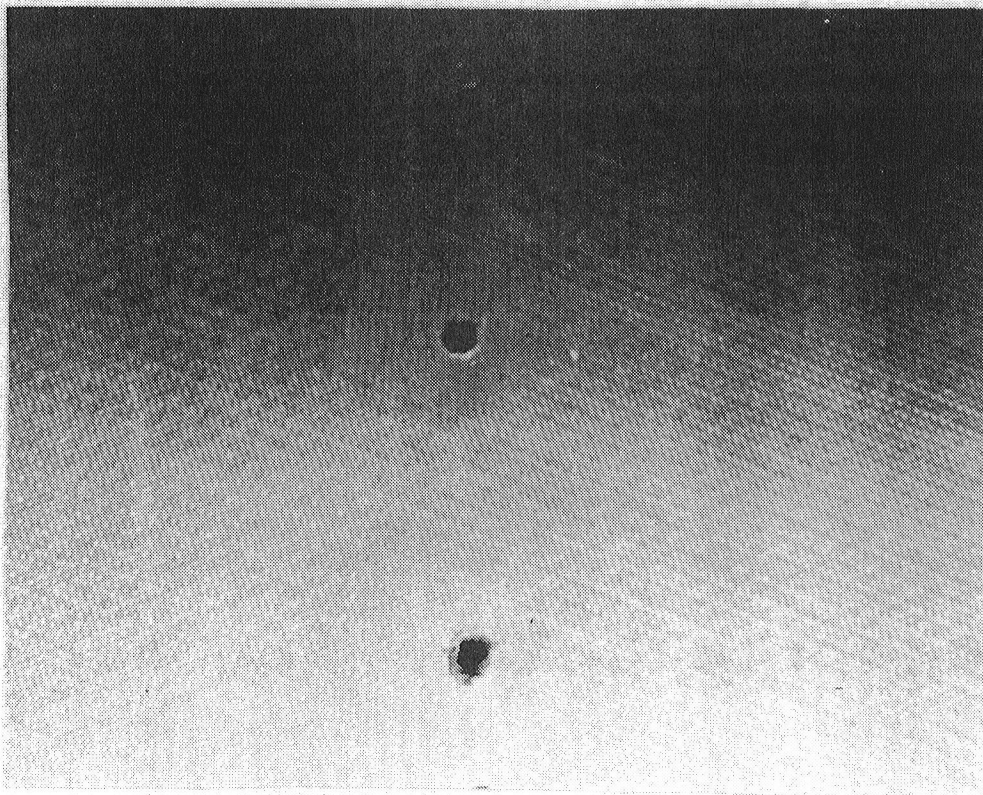


Figure 17. - Air Canada right-hand aft engine fairing - fraying of intercostal holes.

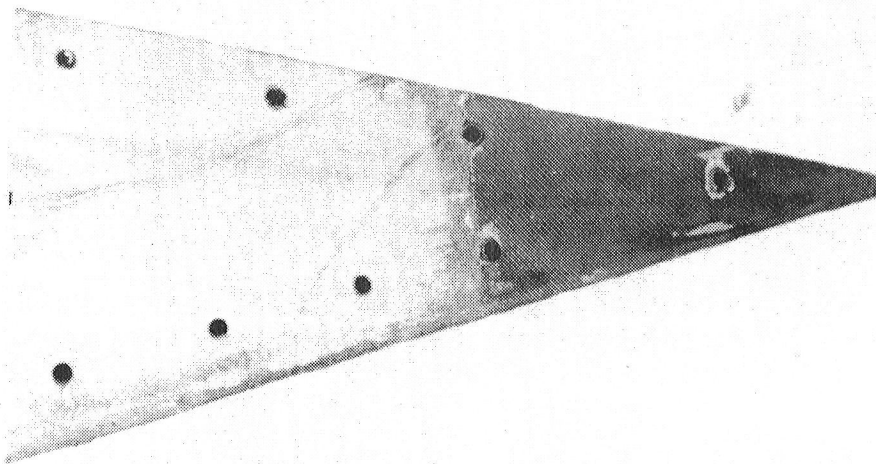


Figure 18. - Air Canada right-hand aft engine fairing - patch at forward edge.

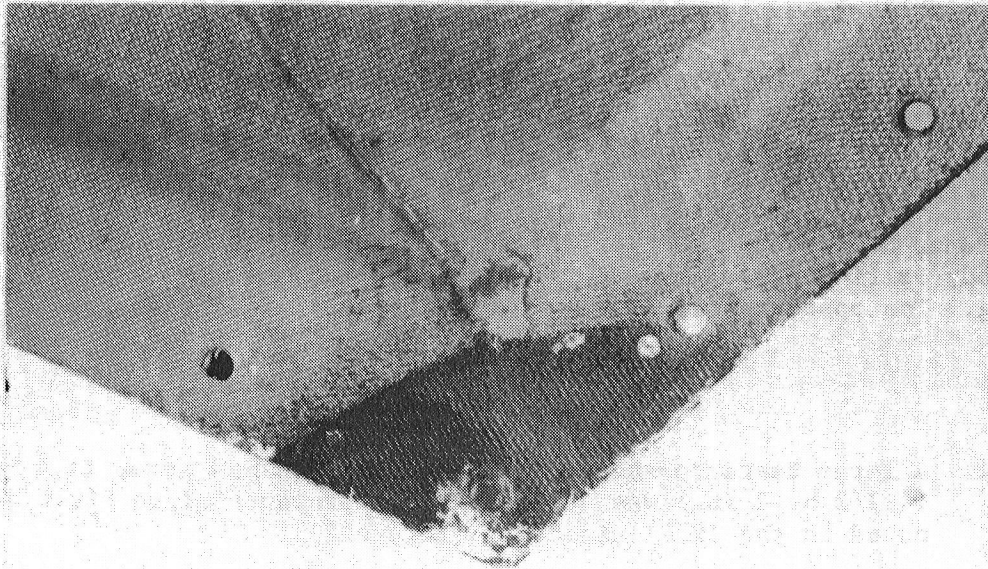


Figure 19. - Air Canada right-hand aft engine fairing - patch at aft edge.

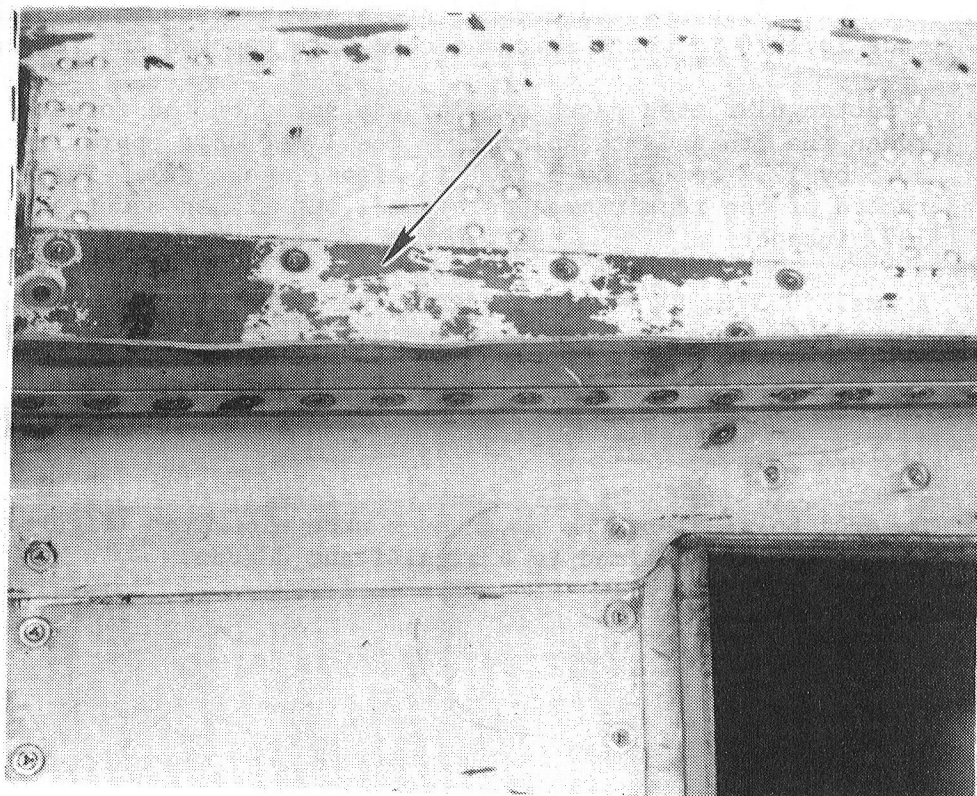


Figure 20. - Air Canada right-hand underwing fillet on aircraft - showing paint loss in upper area.

APPENDIX C

DETAIL OBSERVATIONS OF KEVLAR-49 FAIRING PANELS - TWA AIRCRAFT N31030 (SERIAL NO. 1111), NOVEMBER 1978

Three of the six Kevlar-49 fairing panels were removed for inspection of fastener holes and inner surface conditions. These were the right-hand wing-body fairing and underwing fillet panels and the left-hand aft engine fairing. The opposite set of parts were inspected in-place on the aircraft.

Right-Hand Wing-Body Fairing

1. A large teardrop-shaped disbonded and crushed area, 11.4 by 2.5 cm (4 1/2 by 1 in.) was unchanged in appearance since first being noted in the 1977 inspection (figure 21).
2. A second disbonded and crushed area, similar to the one described above, was observed in the lower forward area 5.1 by 1.3 cm (2 by 1/2 in.) in area. This was unchanged since the 1977 inspection, but had grown slightly since the initial observation in 1976 at which time it was 2.5 by 0.6 cm (1 by 1/4 in.) in area.
3. Two slight depressions were noted, one in the upper forward and one in the upper aft area.
4. The above disbonds and crushed areas may be associated with repairs made in 1974 in which skin and core were removed and replaced.
5. A rectangular area patch overlay was noted on the forward edge between the 6th and 7th holes from the lower edge approximately 30.5 by 12.7 cm (12 by 5 in.) in area (figure 22). There is no record of the repair procedure used, but it had occurred since the 1977 inspection.
6. A small 0.3 cm (1/8 in.) crack in the lower aft area was unchanged in appearance or length since first observed in 1976.
7. Slight fraying was visible on the inner surface around all fastener holes and was more pronounced on the lower edge (figure 23).
8. Several holes along the lower edge were elongated (figure 23); three of these were deformed to a significant degree.

9. The inner surface was deformed around some of the fastener holes (convex on the inner surface) as if partial fastener pull-through had occurred. This deformation was very slight along the top, forward, and aft edges; but was more pronounced along the lower edge.
10. A repaired hole at the lower aft edge was badly frayed and deformed. The original hole had been filled with chopped glass filled epoxy resin and redrilled (figure 23).

Right-Hand Underwing Fillet

1. The panel was weighed using an accurate balance brought from Lockheed. The weight was 663.75 gms (1.463 lb).
2. No damage or defects were observed on either the exterior or inner surfaces.
3. Fraying was observed on all fastener holes and was more pronounced on the inner surface (figure 24). Five holes (out of 20) were frayed noticeably worse than the others.
4. About half the holes were deformed and elongated. Four holes were significantly deformed to a maximum 0.6 cm (1/4 in.) dimension from the original 0.5 cm (3/16 in.) hole size (figure 24). There was no correlation between the badly frayed and badly elongated holes.

Left-Hand Aft Engine Fairing

1. No damage was observed on either surface. Some paint cracking was noted in the aft area but there was no evidence of associated damage to the Kevlar-49 skins.
2. The fastener holes showed very little fraying (figure 25). This part had all fastener holes relocated upon re-installation into a second L-1011. A surface layer of 120 glass was applied to both surfaces before drilling apparently eliminating the fraying.
3. About one-third of the fastener holes (37 total) were deformed and elongated. Fourteen of these were significantly elongated to 0.6 cm (1/4 in.) or in two cases 0.8 cm (5/16 in.) maximum dimensions from the original 0.5 cm (3/16 in.) hole size. The holes with slight elongation included several intercostal holes which go through the honeycomb core.

Left-Hand Wing-Body Fairing

1. A deep gouge 1.3 cm (1/2 in.) in length was observed in the upper forward area. A disbonded area extended in a 1.3 cm (1/2 in.) radius arc forward of the crack. This damage had occurred since the previous inspection.
2. A small crack 0.3 cm (1/8 in.) long had not changed in appearance or extent since first observed in 1977.

Left-Hand Underwing Fillet

1. No evidence of damage or defects. Only the lower portion of this part was visible.

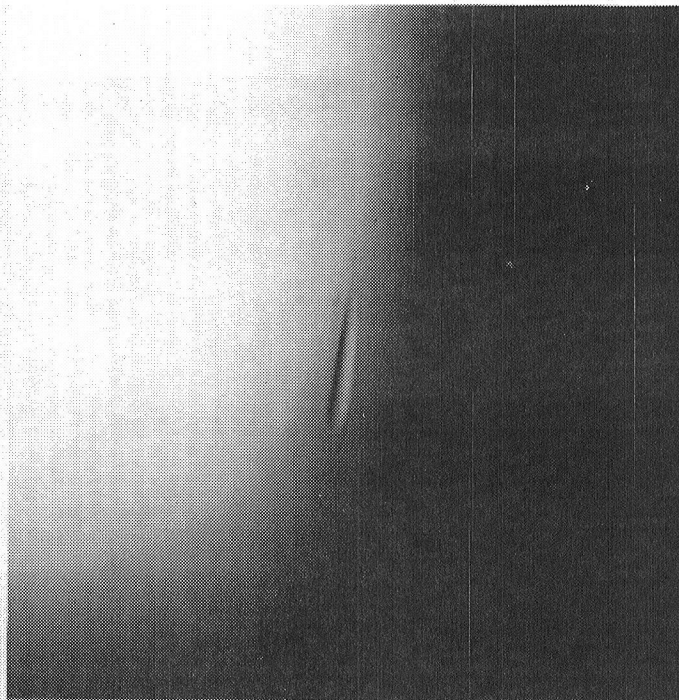


Figure 21. - TWA right-hand wing-body fairing - crushed and disbonded area, exterior surface 11.4 by 2.5 cm (4.5 by 1 inch).

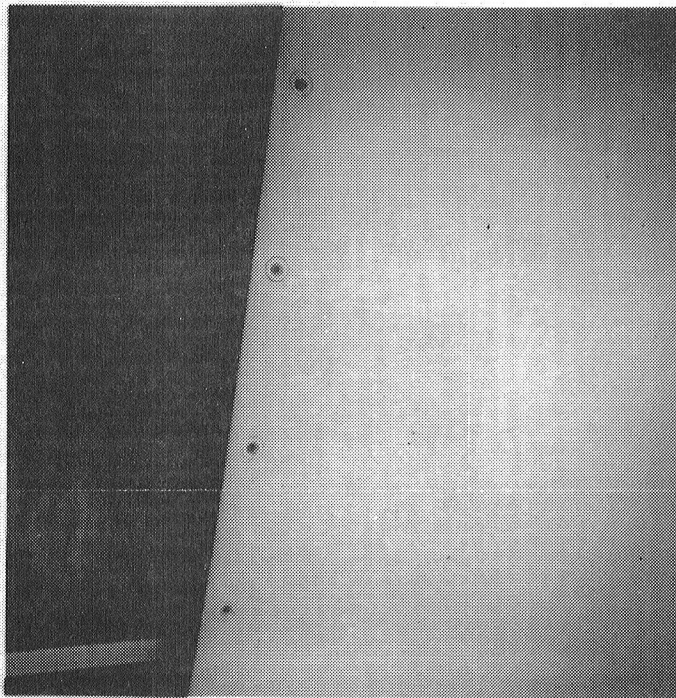


Figure 22. - TWA right-hand wing-body fairing - rectangular patch area, 30.5 by 12.7 cm (12 by 5 inches).

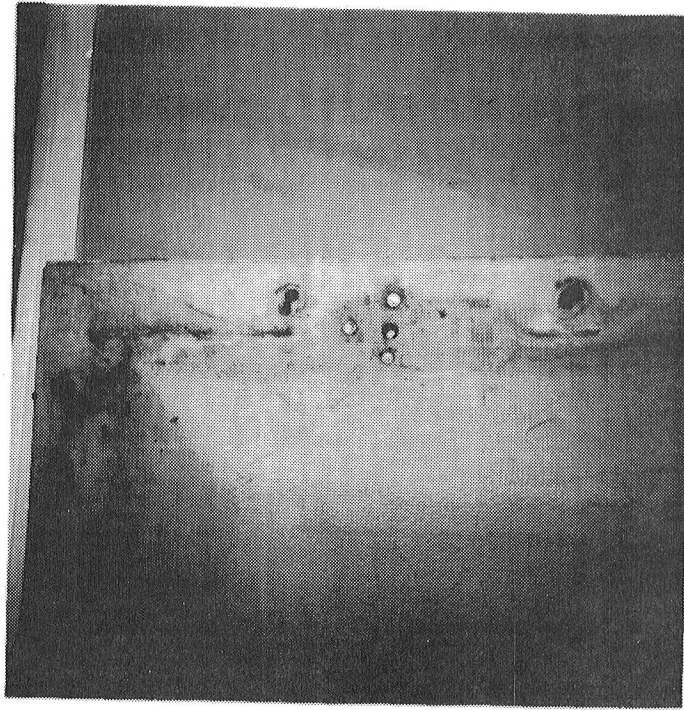


Figure 23. - TWA right-hand wing-body fairing - frayed and elongated holes, with repaired holes showing fraying and deformation.

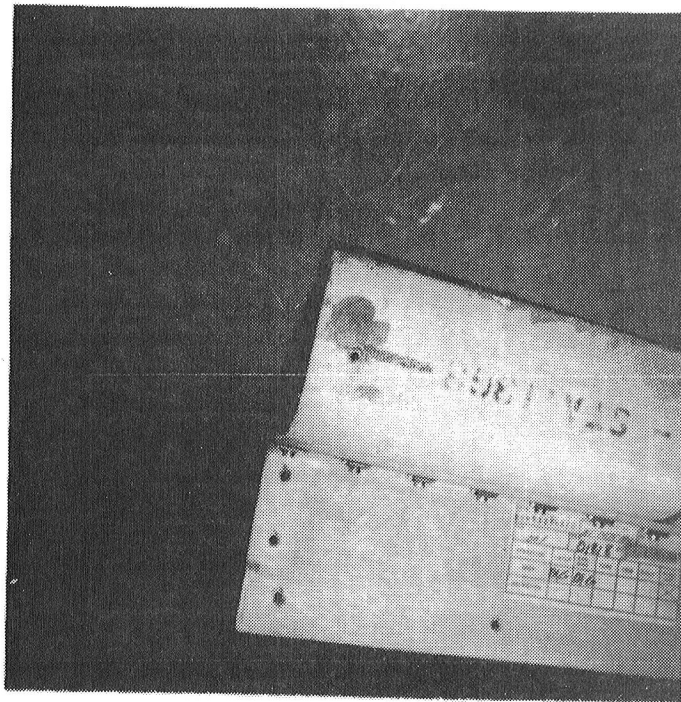


Figure 24. - TWA right-hand underwing fillet - frayed
holes.

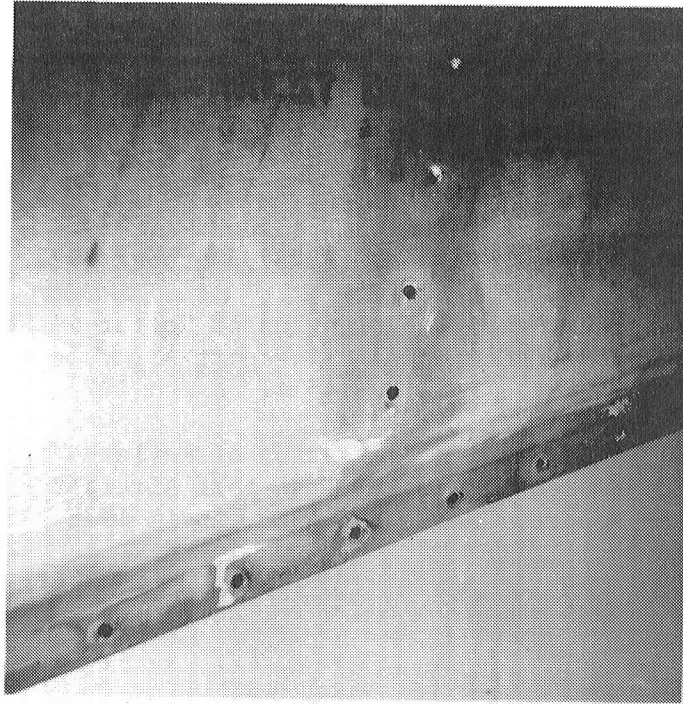


Figure 25. - TWA left-hand aft engine fairing - showing
absence of fraying due to glass surface ply.

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16. ABSTRACT <p>Kevlar-49 fairing panels, installed as flight service components on three L-1011s, were inspected after five years' service. There are six Kevlar-49 panels on each aircraft: a left-hand and right-hand set of a wing-body sandwich fairing; a solid laminate under-wing fillet panel; and a 150°C (300°F) service aft engine fairing. The three L-1011s include one each in service with Eastern, Air Canada, and TWA. The fairings have accumulated a total of 40,534 hours, with one ship set having 16,091 hours service as of Feb. 11, 1979. The inspections were conducted at the airlines' major maintenance bases with the participation of Lockheed Engineering.</p> <p>The Kevlar-49 components were found to be performing satisfactorily in service with no major problems, or any condition requiring corrective action. The only defects noted were minor impact damage, and a minor degree of fastener hole fraying and elongation. These are for the most part comparable to damage noted on fiberglass fairings.</p> <p>The service history to date indicates that Kevlar-49 epoxy composite materials have satisfactory service characteristics for use in aircraft secondary structure.</p>					
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